



# Background: Climate Prediction

Pablo Ortega

Climate Prediction Group, Earth Sciences Department



**TRIATLAS KOM – Bergen – 27/29 August 2019**

# Background: Climate Prediction



# Biogeochemistry Prediction

Pablo Ortega

Climate Prediction Group, Earth Sciences Department

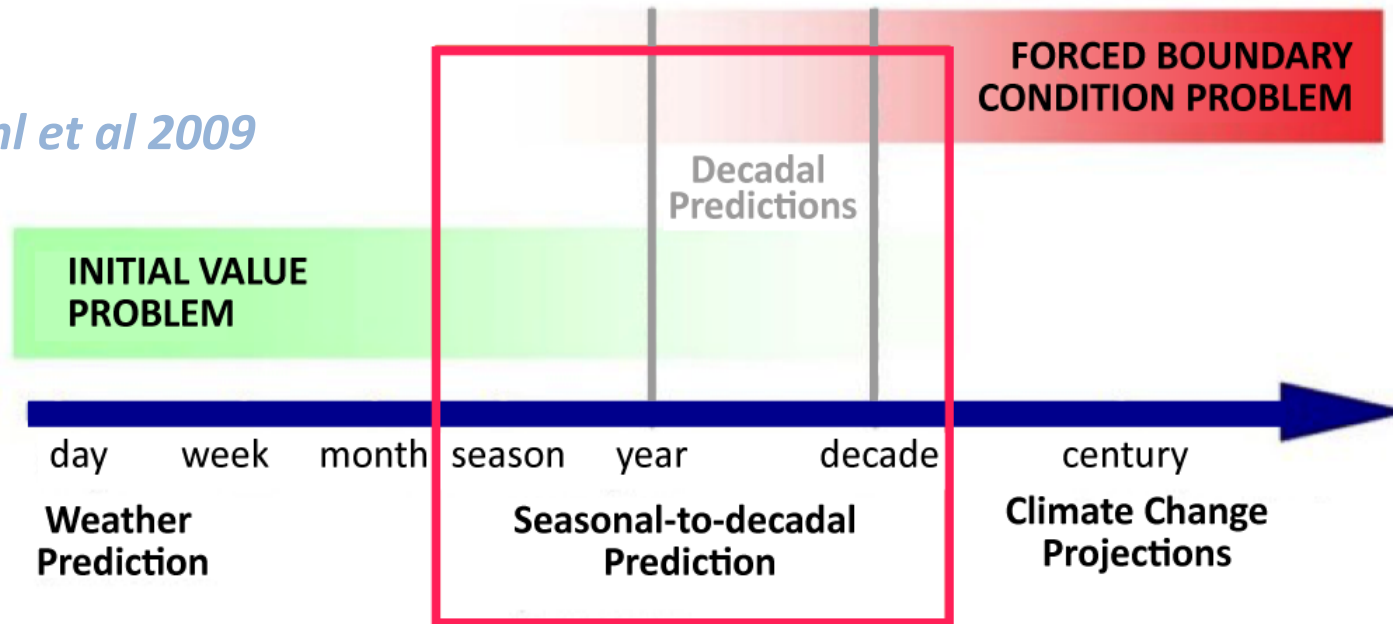
# Cornerstones of Climate Prediction



Barcelona  
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*Meehl et al 2009*



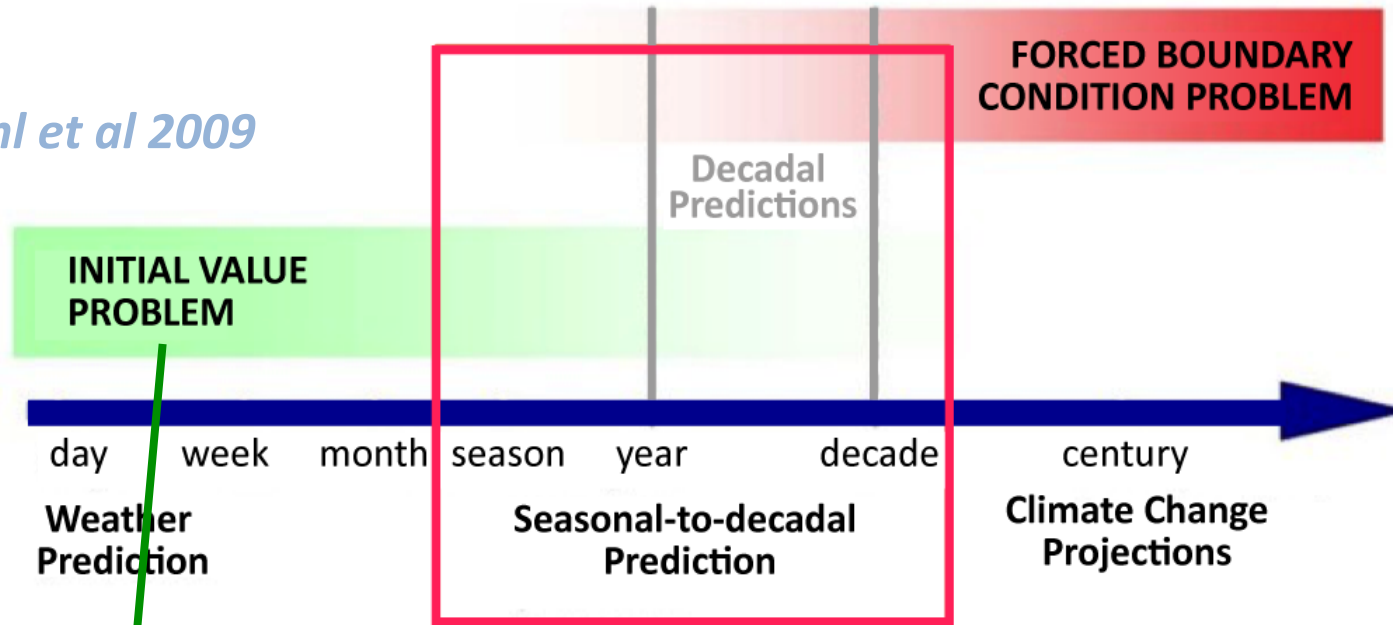
# Cornerstones of Climate Prediction



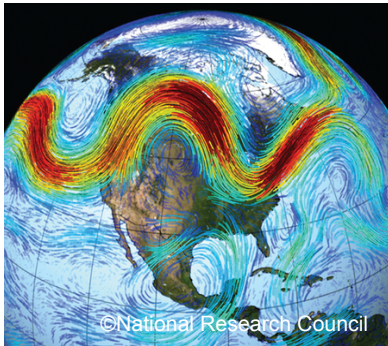
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*Meehl et al 2009*



Current Meteorological state



**Correct Initialization of internal sources of predictability**



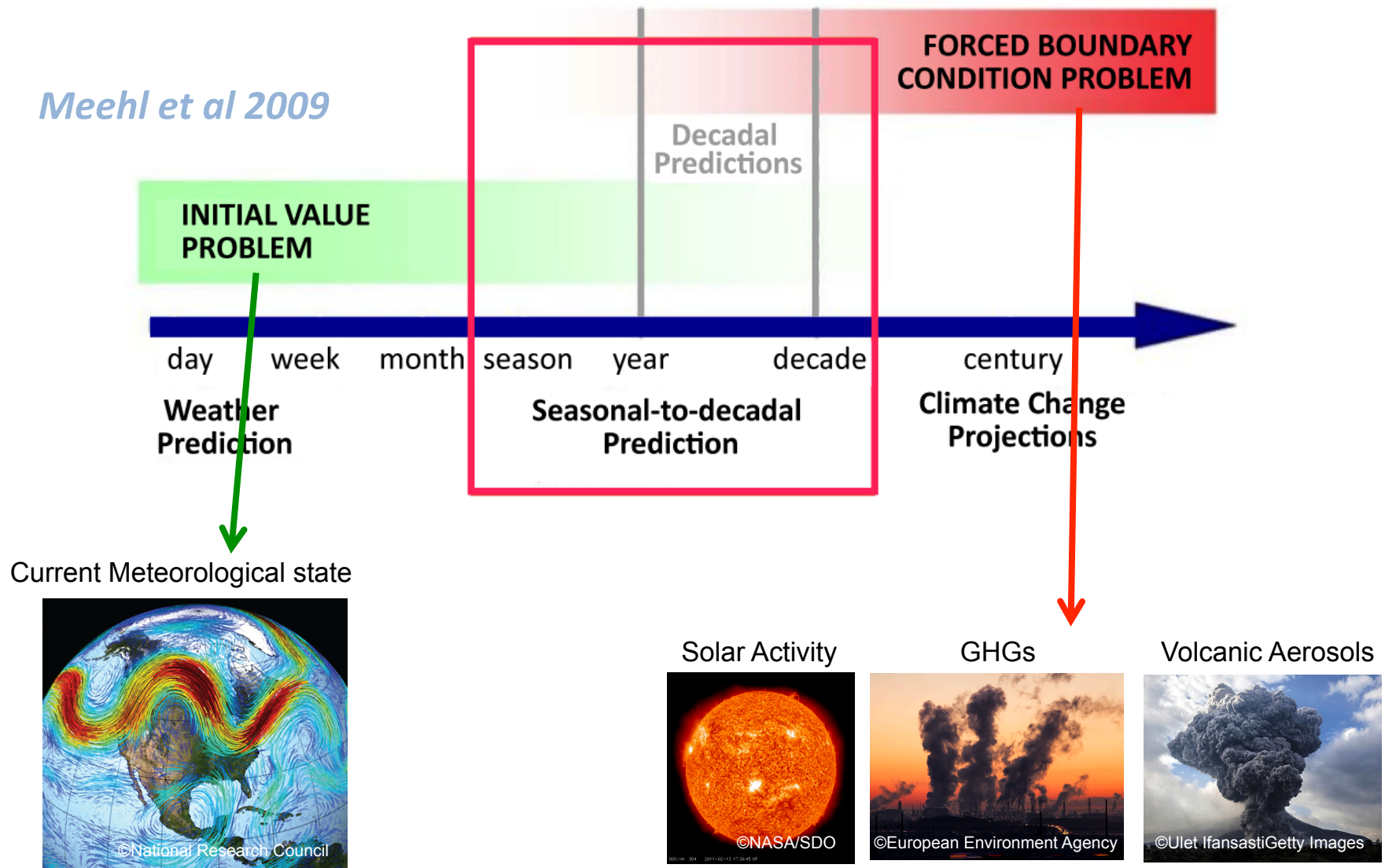
# Cornerstones of Climate Prediction



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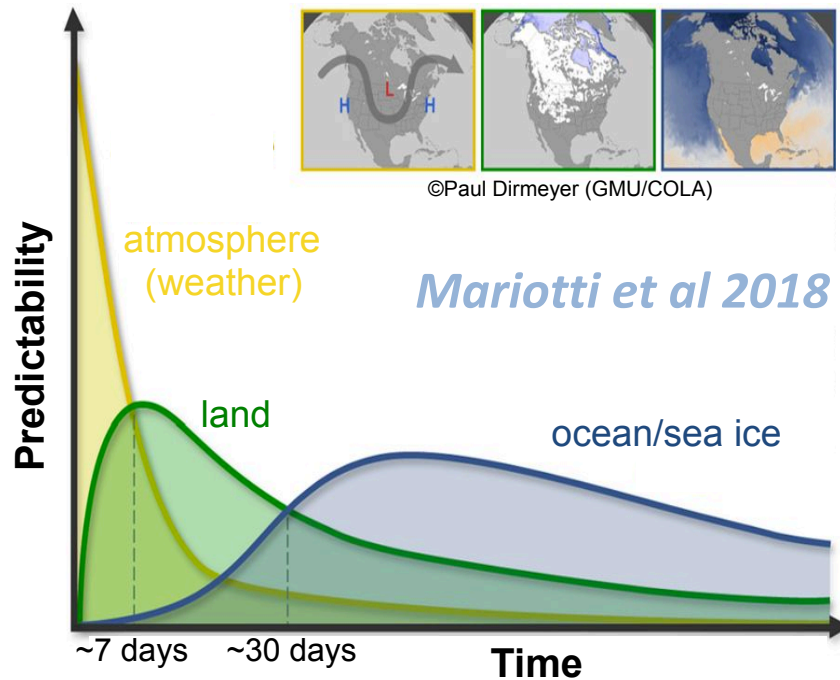


*Meehl et al 2009*



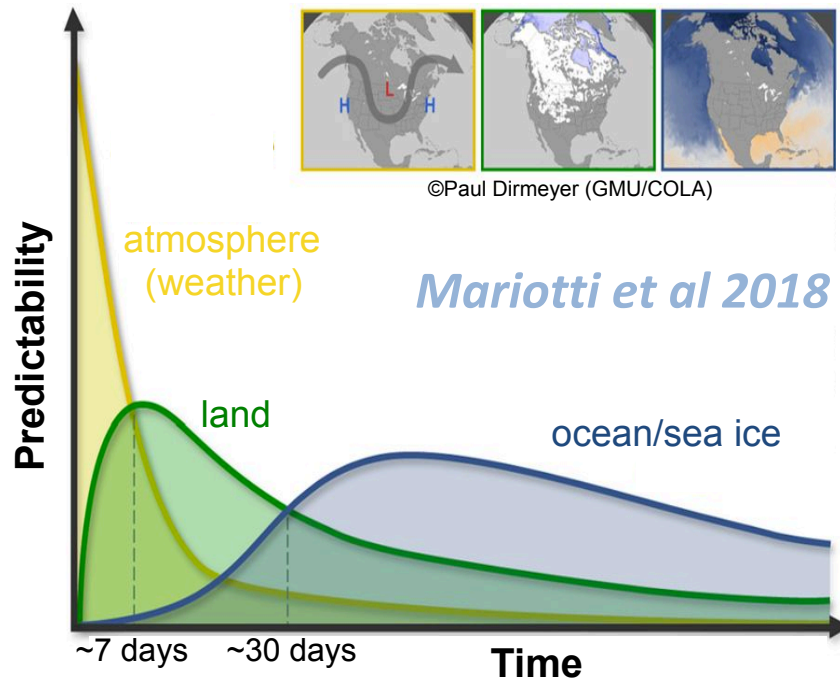
**Correct Initialization of internal sources of predictability**

**Good guess of future changes in the forcing**



Weather prediction  $\xrightarrow[\text{horizon}]{\text{time}}$  ~ 10 days

Because of the chaotic nature  
of atmospheric variability



Weather prediction  $\xrightarrow[\text{horizon}]{\text{time}}$  ~ 10 days

Because of the chaotic nature of atmospheric variability

Climate prediction  $\xrightarrow[\text{horizon}]{\text{time}}$  Weeks  
Decades

It relies on the longer memory of other elements of the climate system

ocean

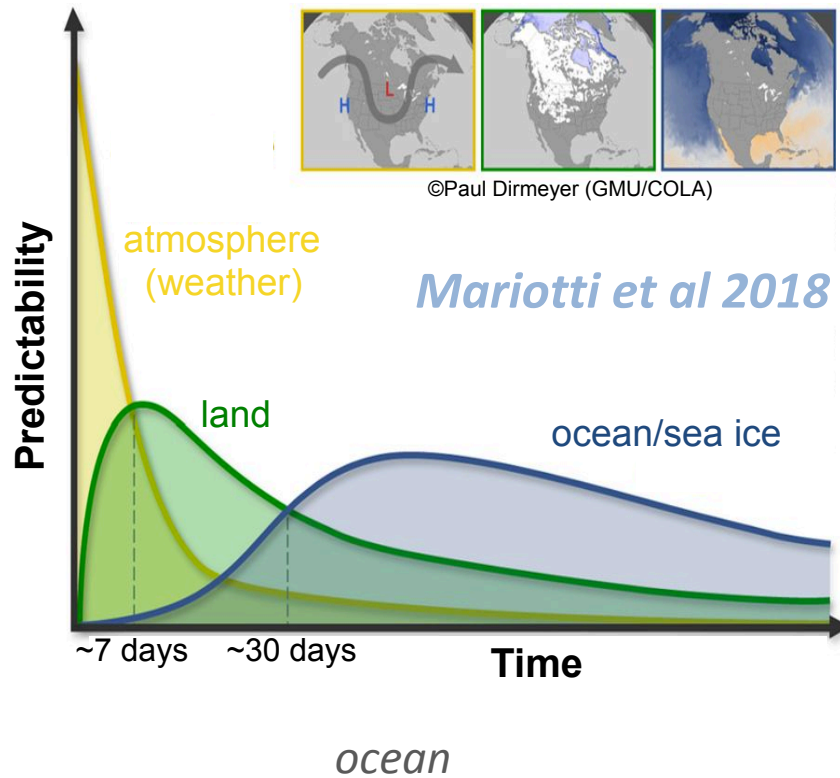


sea ice

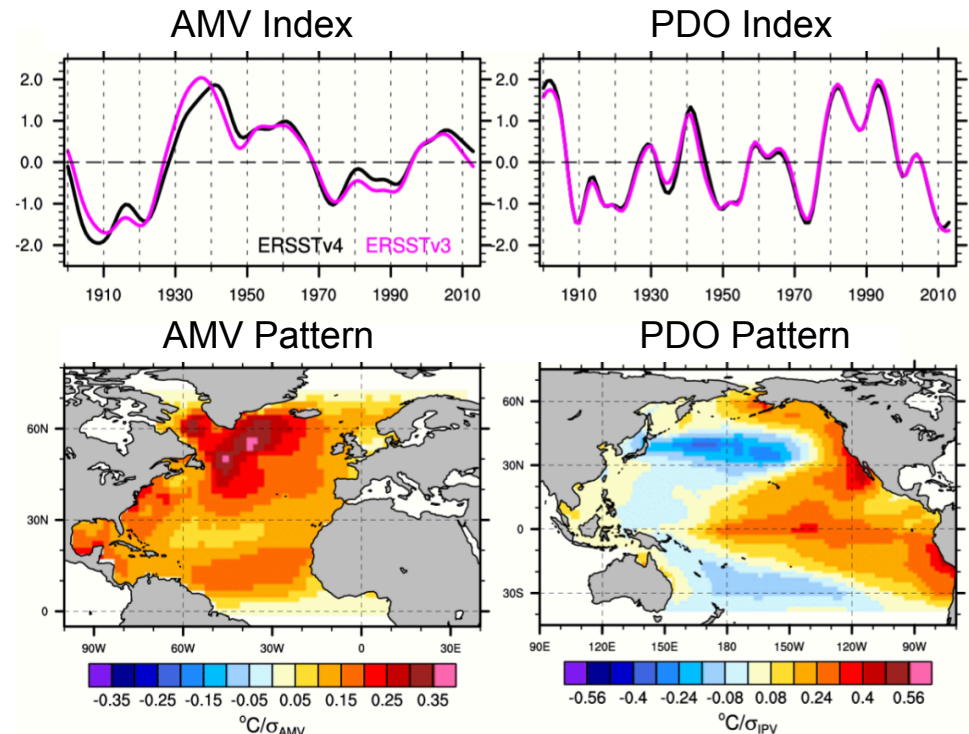


soil moisture



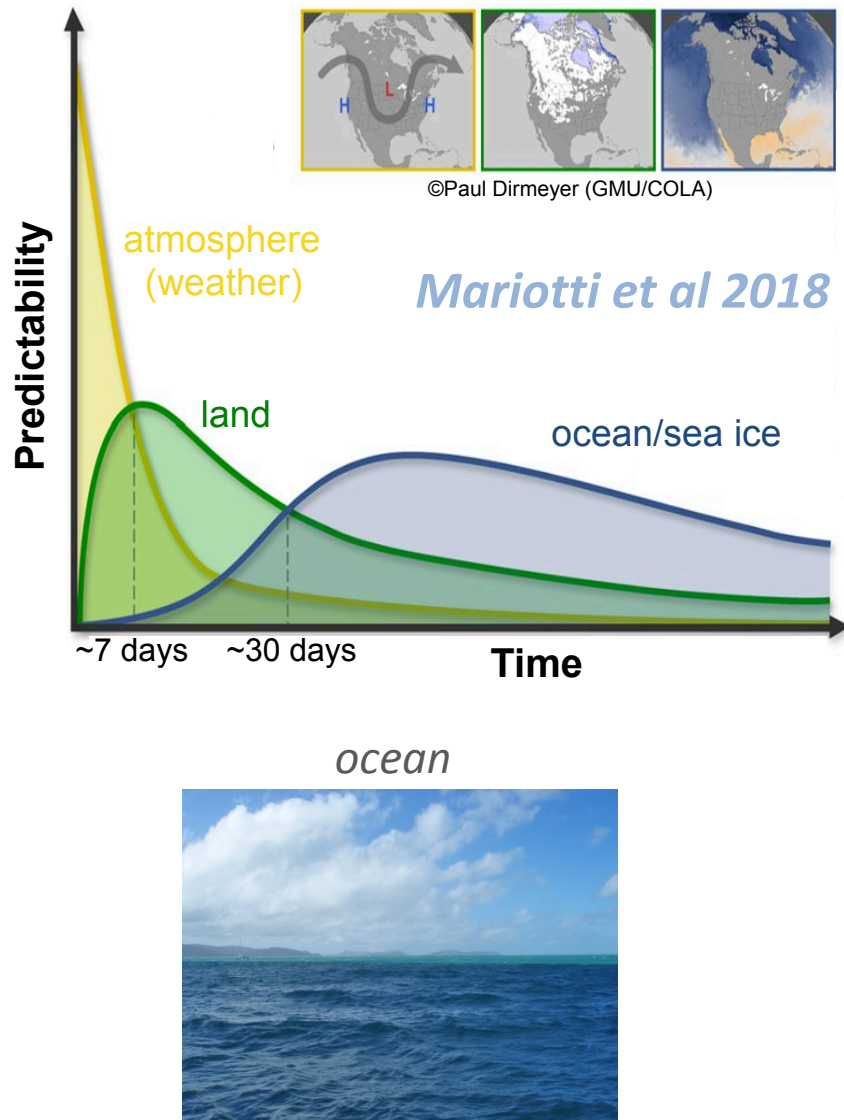


The **ocean** exhibits modes of **decadal variability** both in the **Atlantic** and **Pacific** basins...



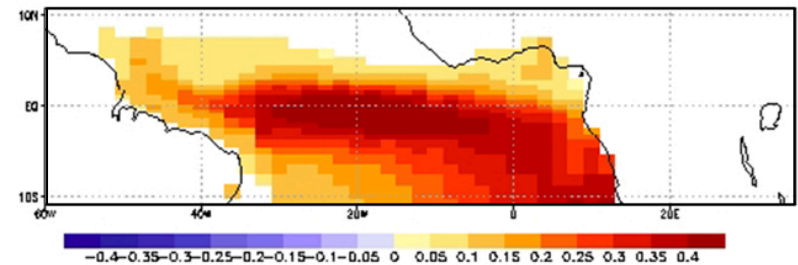
*Cassou et al,*  
*Technical Note for DCP-Component C*



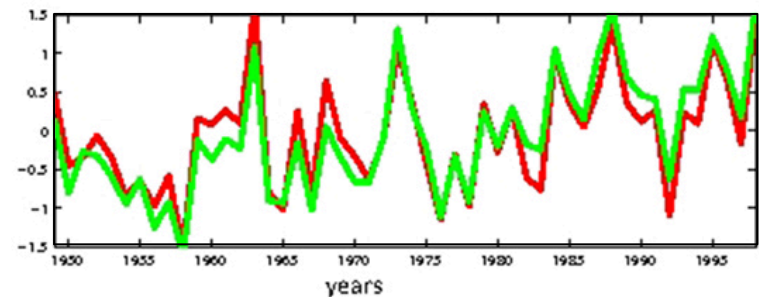


... and also modes of **interannual variability**

Equatorial Atlantic Mode/ Atlantic El Niño



Timeseries Equatorial Atlantic (JJAS)

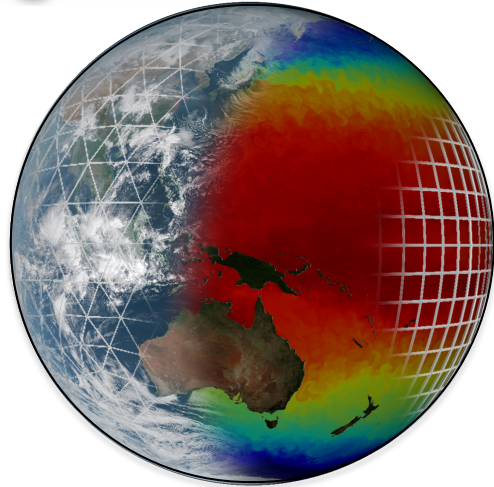


*Polo et al 2015*

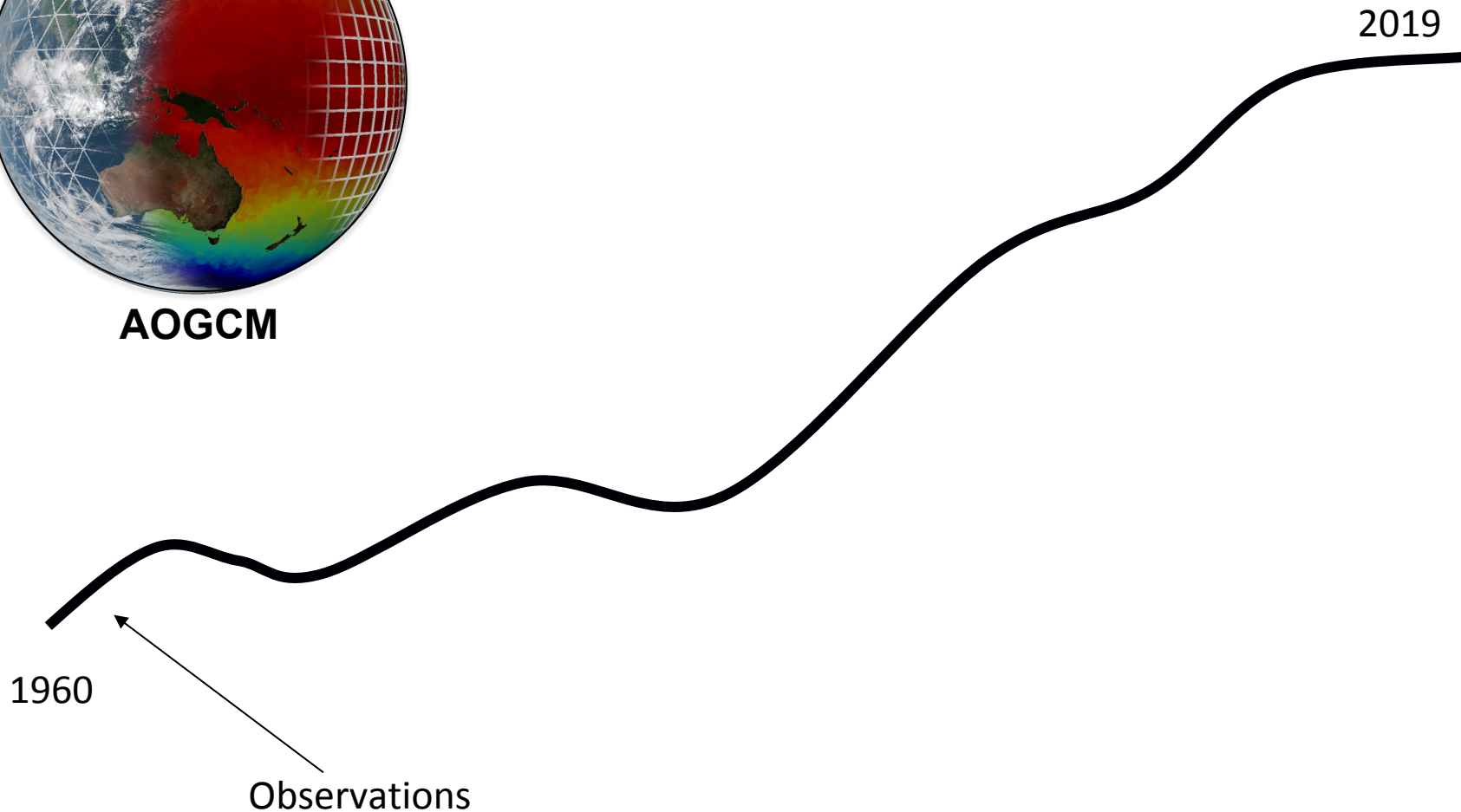
# Implementing a Climate Prediction System



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**AOGCM**



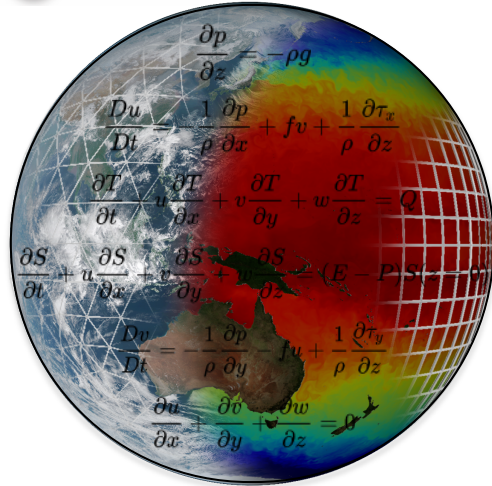


# Implementing a Climate Prediction System

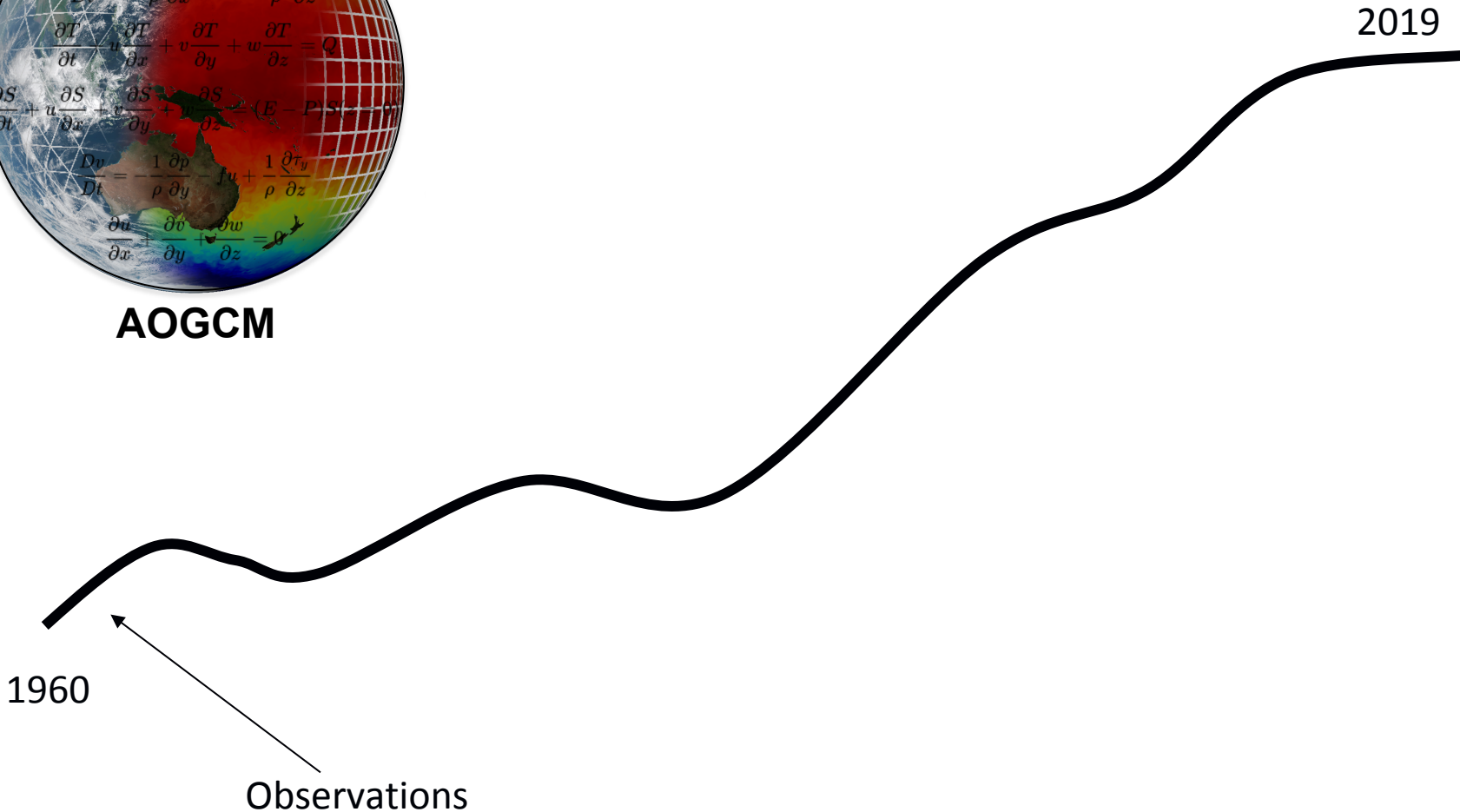


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**AOGCM**

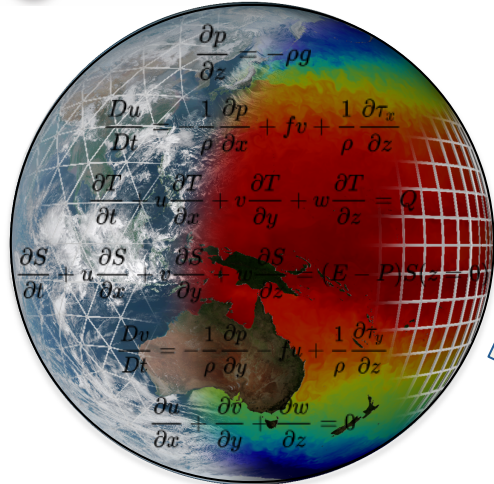


# Implementing a Climate Prediction System



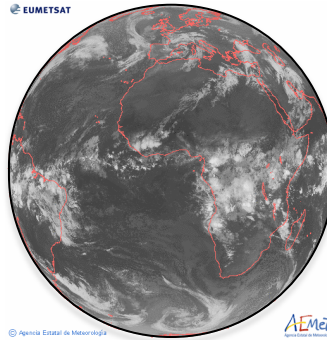
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**AOGCM**

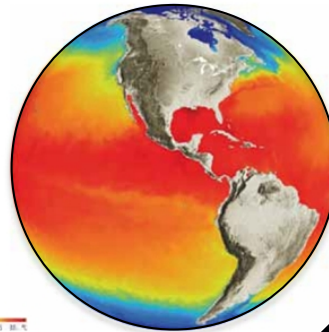
EUMETSAT



© Agencia Estatal de Meteorología

**Observations**

AEMet



2 3 11 13 15 17 19 21

Ensemble  
prediction started  
1 Nov 2019

2019

**Forecast**

1960

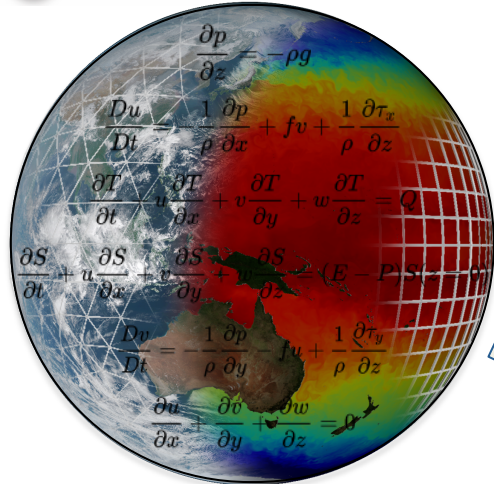
Observations

2019

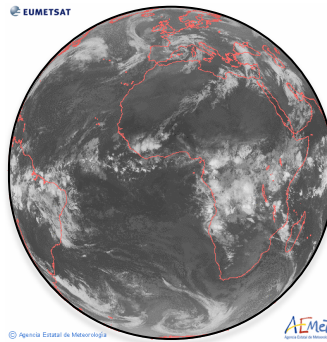
# Implementing a Climate Prediction System



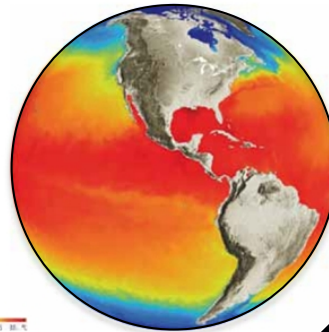
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AOGCM



Observations



Ensemble  
prediction started  
1 Nov 2019

2019

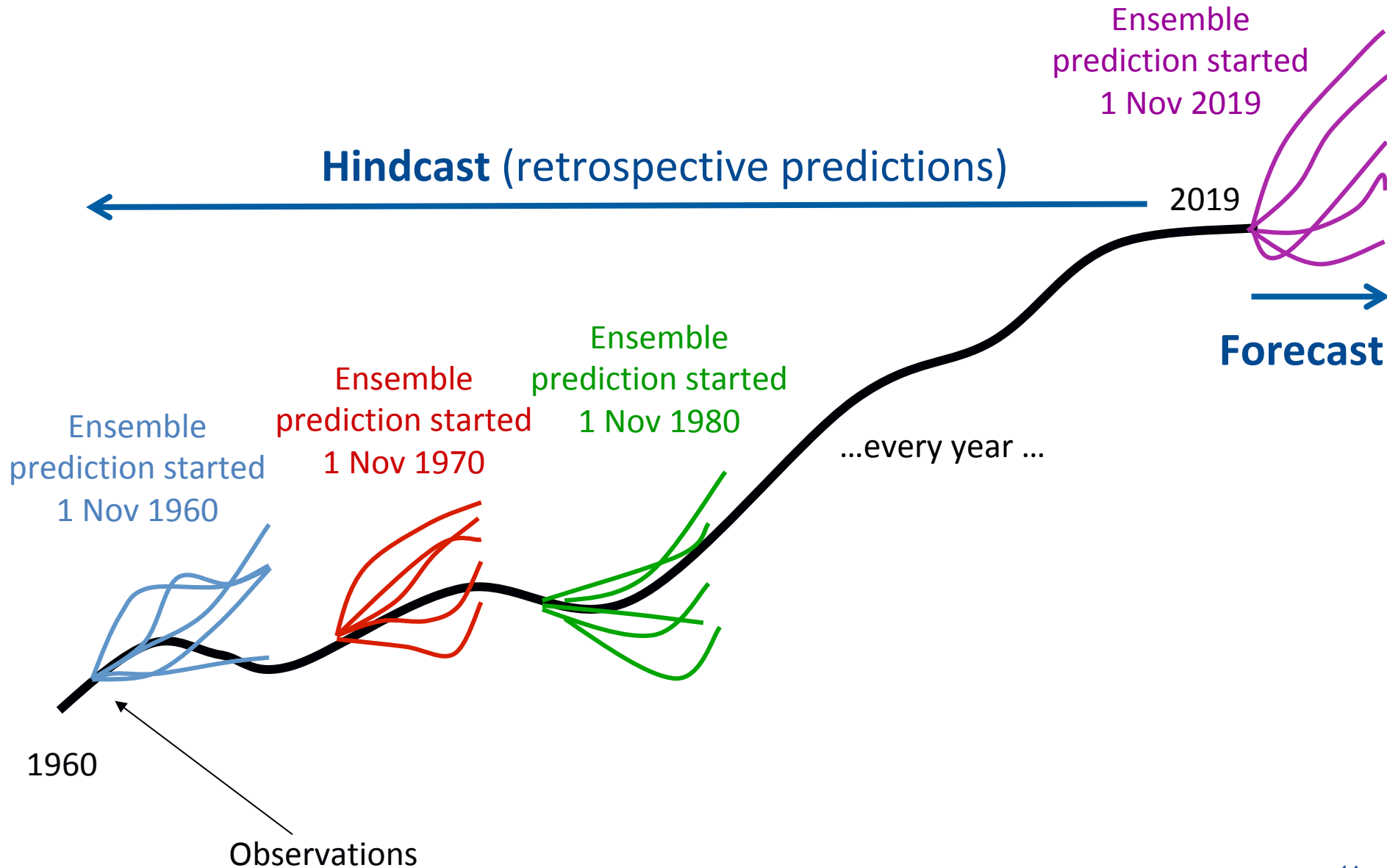
Forecast

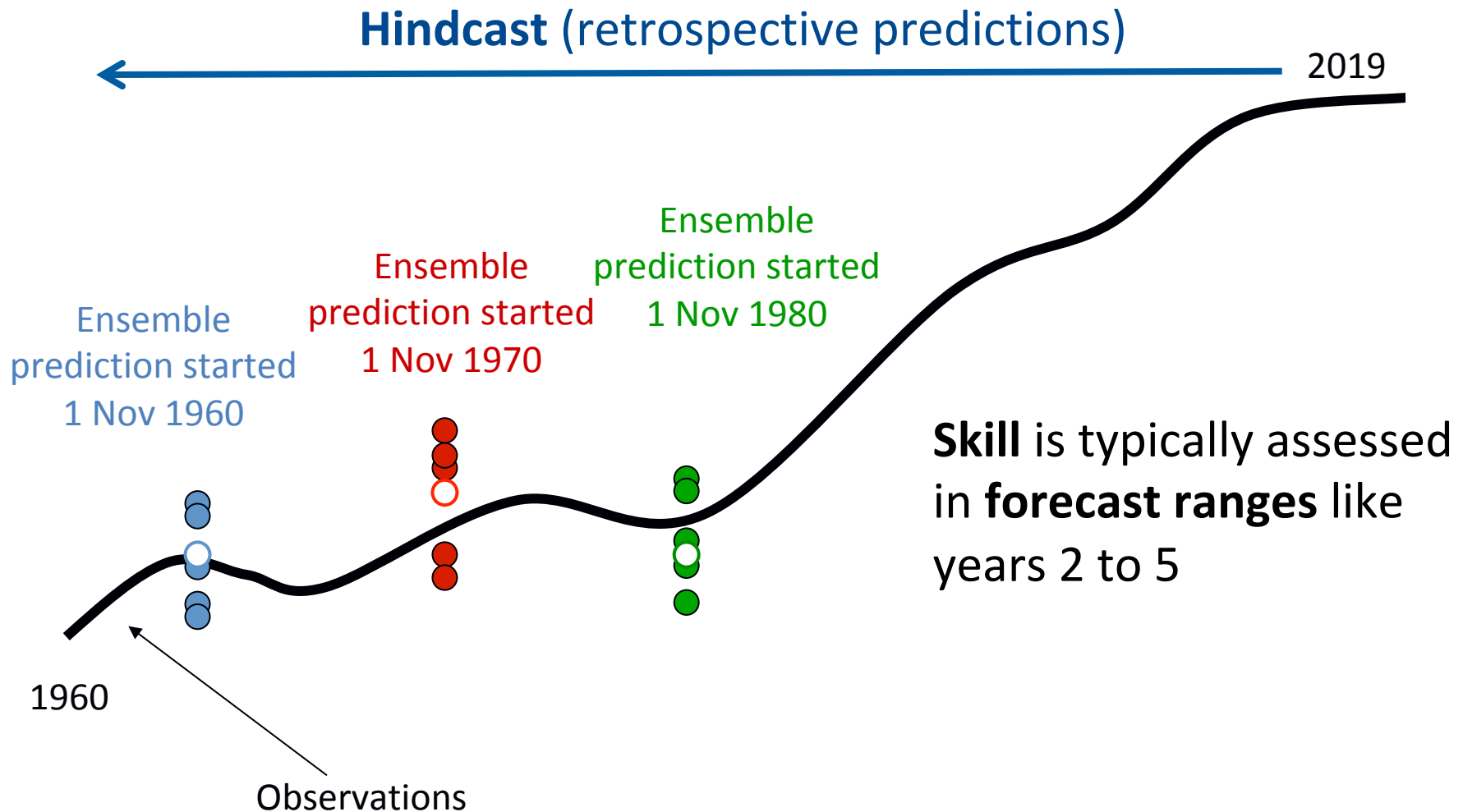
But how much  
can we trust it?

1960

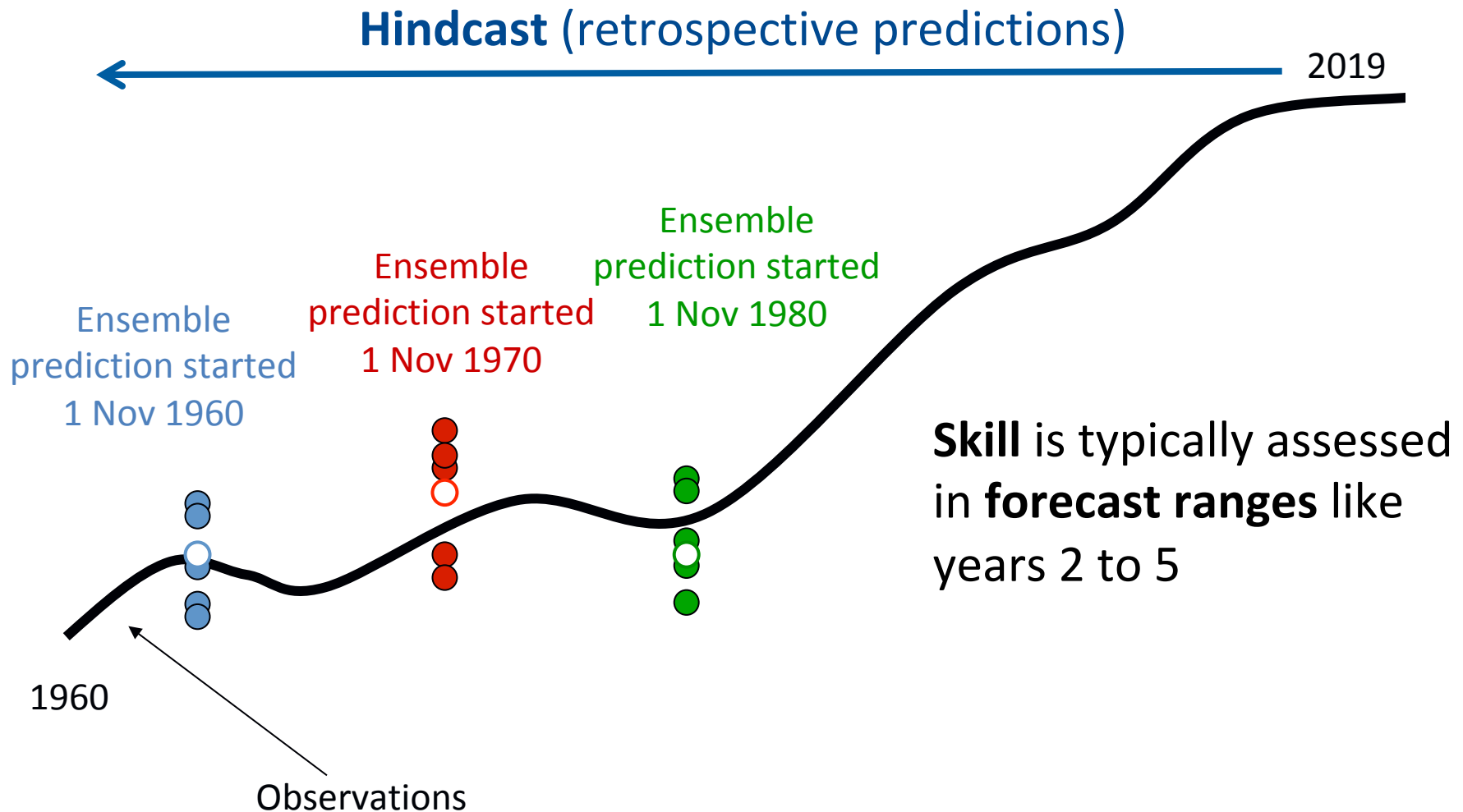
Observations

2019



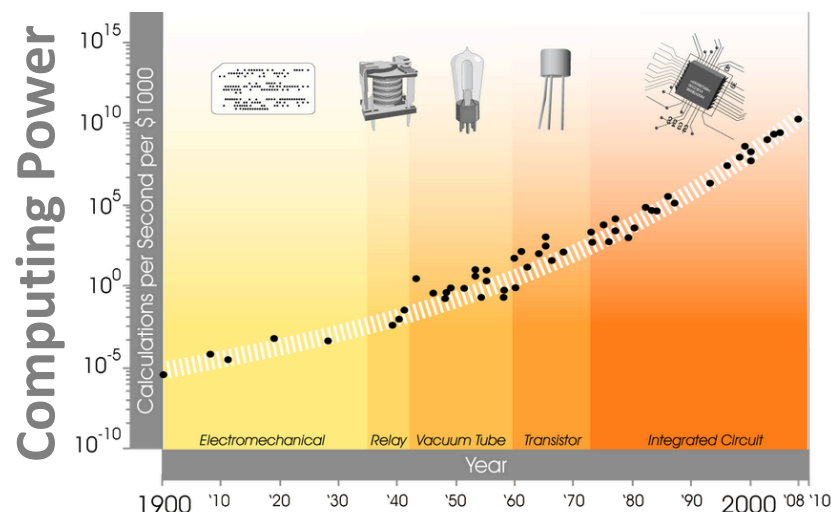


**High volume of simulation years!!** E.g.: 10 members x 59 start dates x 10 forecast yrs





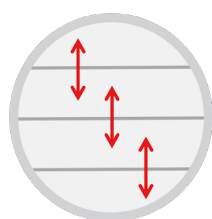
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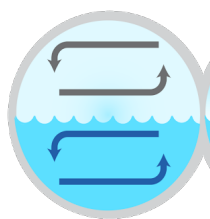
First predictions  
with AOGCMs

First predictions  
with ESMs

Model Complexity



1890s  
Radiative  
Transfer



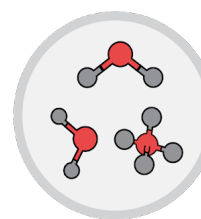
1960s  
Non-Linear  
Fluid Dynamics



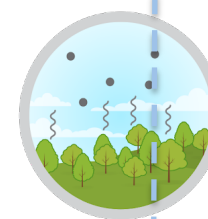
Hydrological  
Cycle



1970s  
Sea Ice and  
Land Surface



1990s  
Atmospheric  
Chemistry



2000s  
Aerosols and  
Vegetation



2010s  
Biogeochemical  
Cycles and Carbon

Energy Balance Models

Atmosphere-Ocean General Circulation Models

Earth System Models

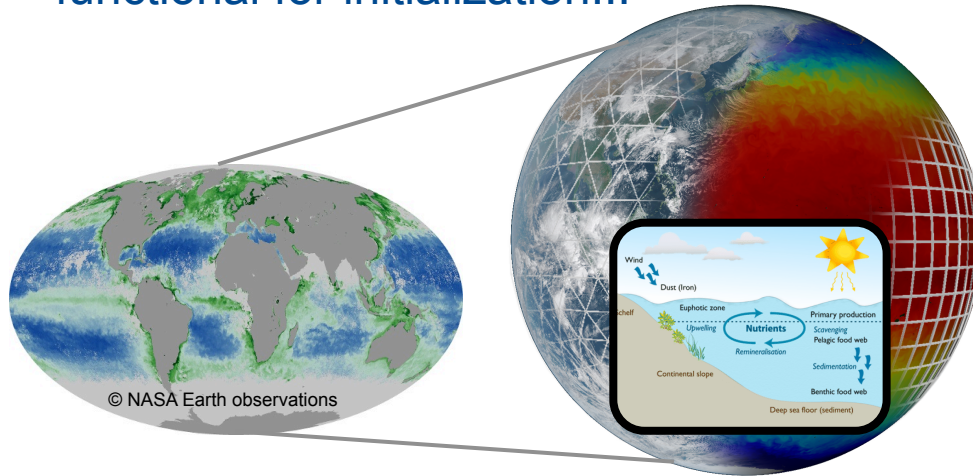
# First results with ESMs are encouraging



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Assimilation of BGC fields still not  
functional for initialization...



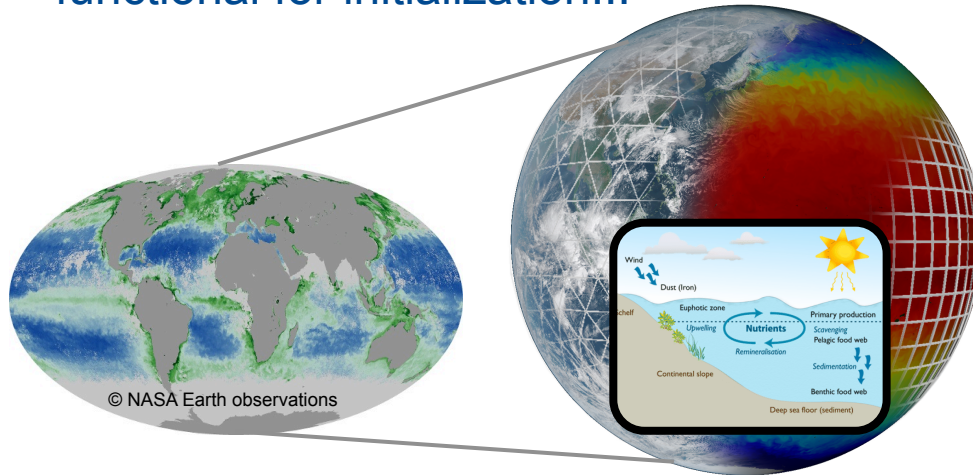
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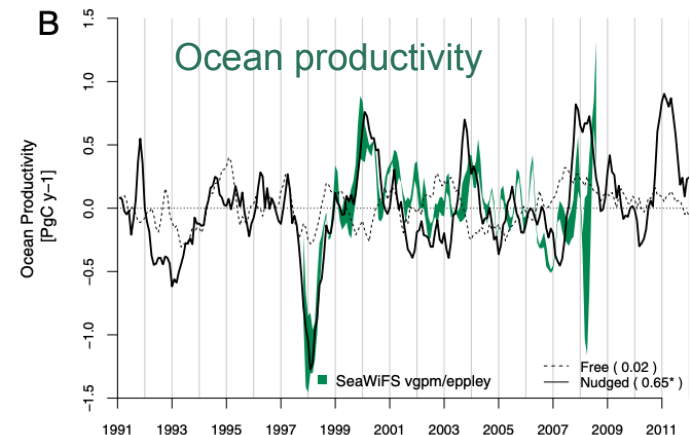
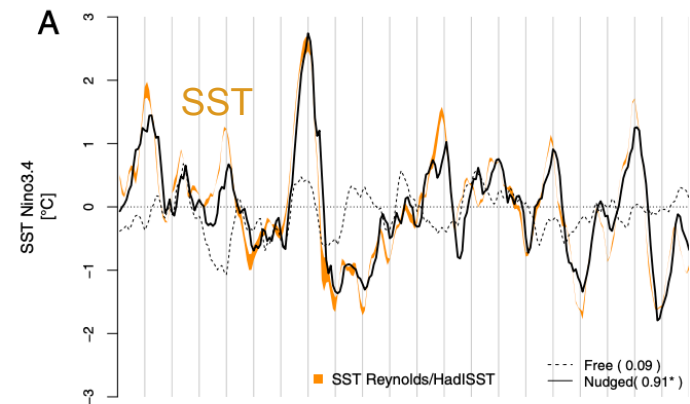
Assimilation of BGC fields still not functional for initialization...



*Seferian et al 2014*

**IPSL ESM**

...yet **Net Primary Production** can be fairly well constrained from SSTs...



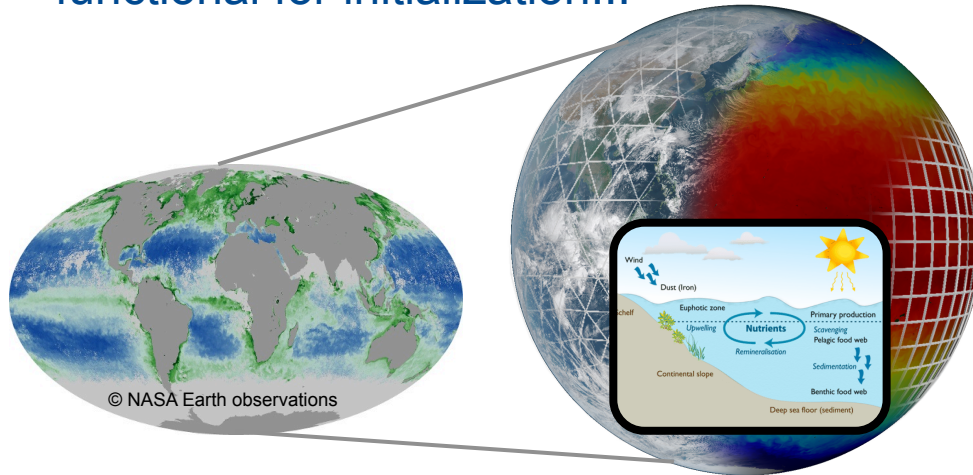
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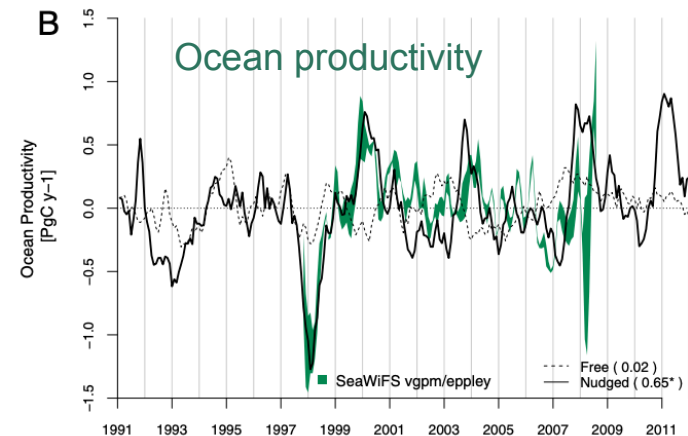
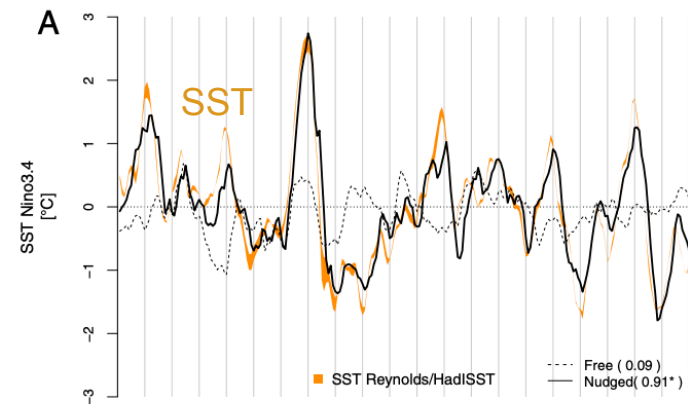
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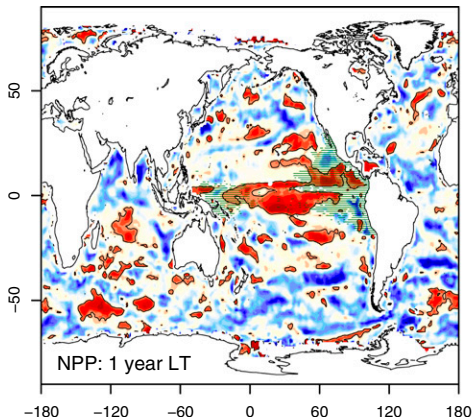
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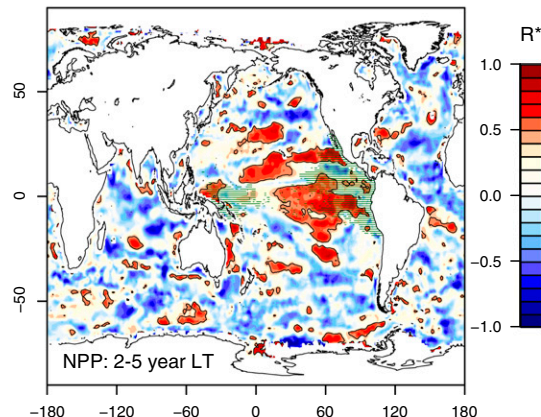


...and **even predictable** several years ahead

ACC of NPP 1 year



ACC of NPP 2-5 years

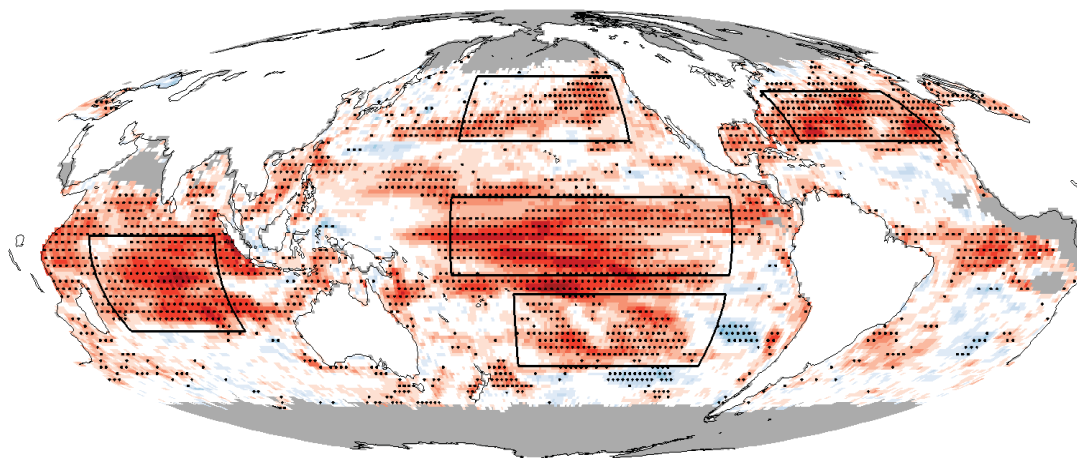


Results are even more promising at the **seasonal scale**, in particular for the **Atlantic Ocean**

*Park et al 2019*

**GFDL ESM**

ACC of Chlorophyll: 1-3 months





# First results with ESMs are encouraging



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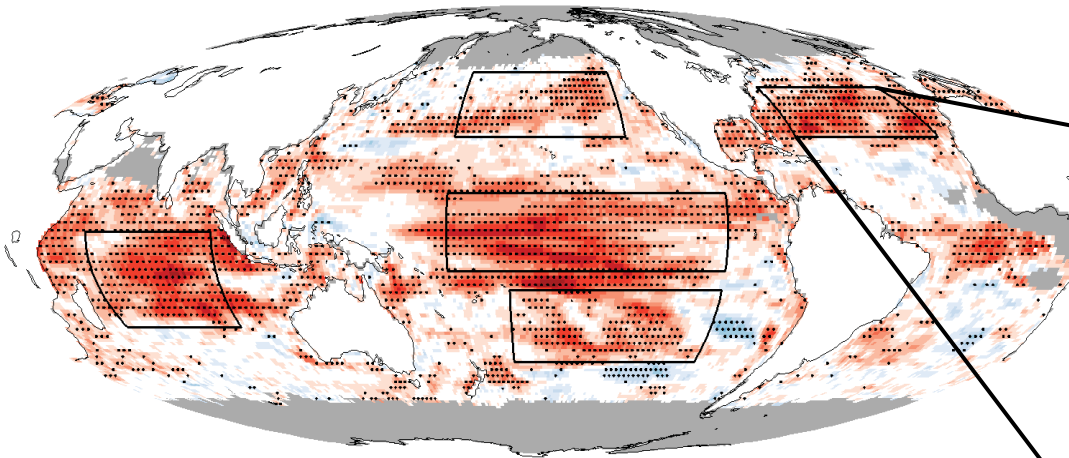


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*Park et al 2019*

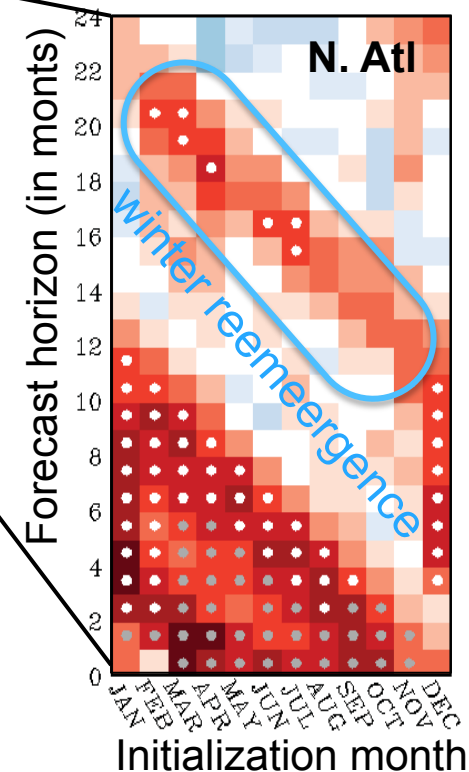
**GFDL ESM**

ACC of Chlorophyll: 1-3 months



But skillful forecast ranges highly depend on initialization month

ACC of Chlorophyll ;



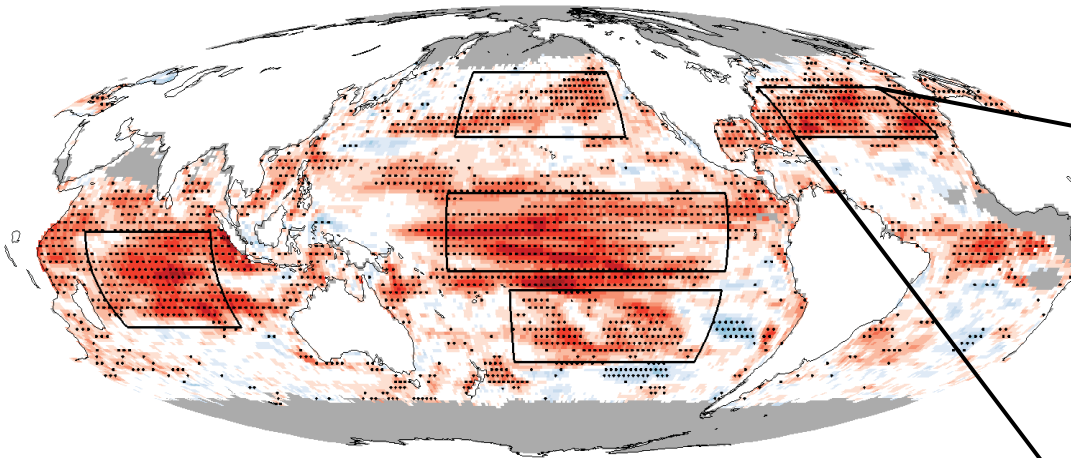


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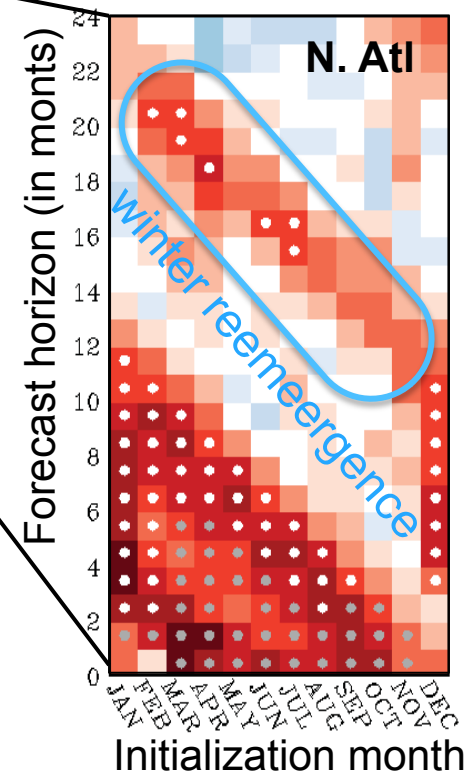
**GFDL ESM**

ACC of Chlorophyll: 1-3 months



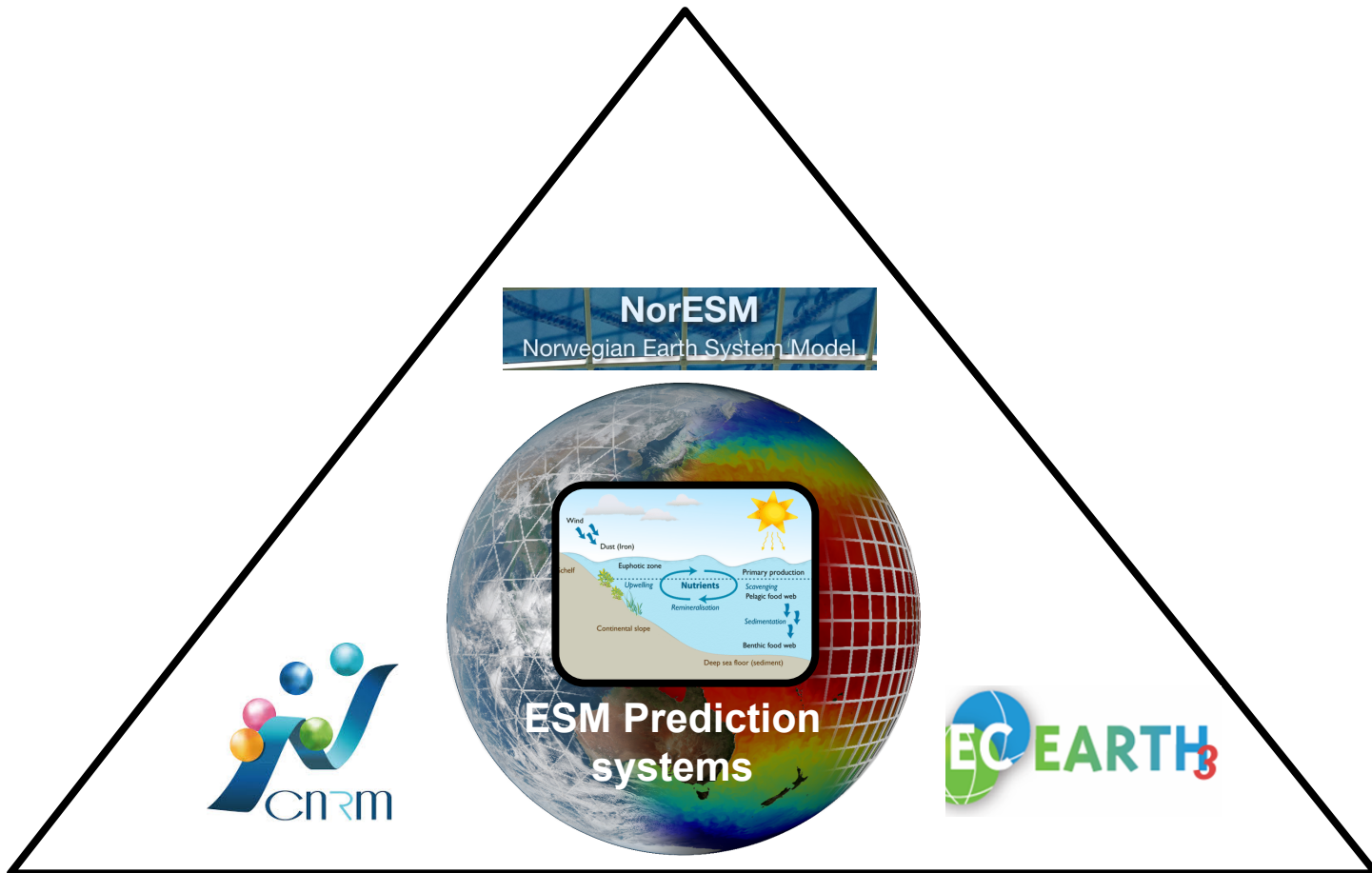
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ACC of Chlorophyll ;

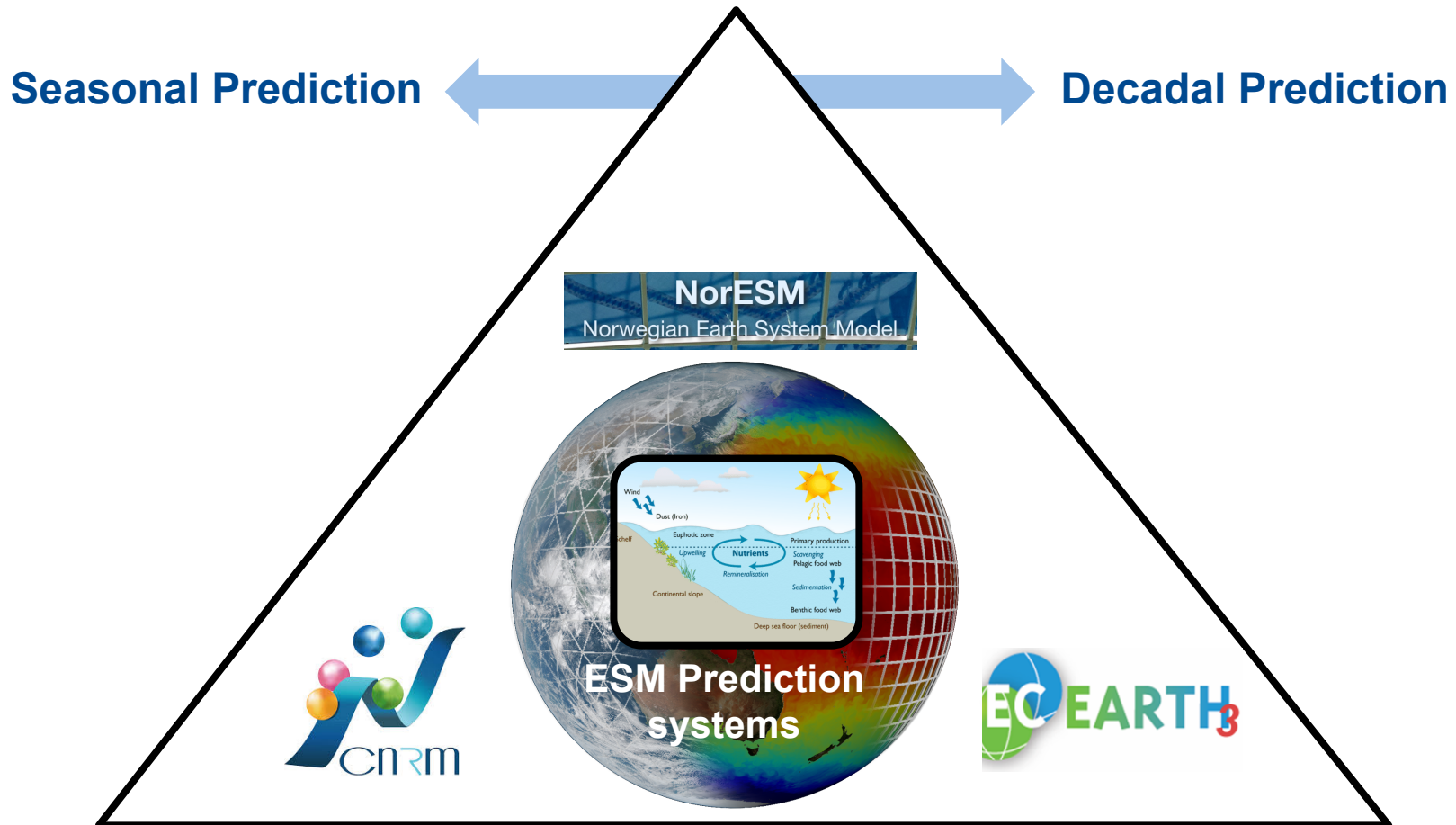


**Are these result  
model dependent?**

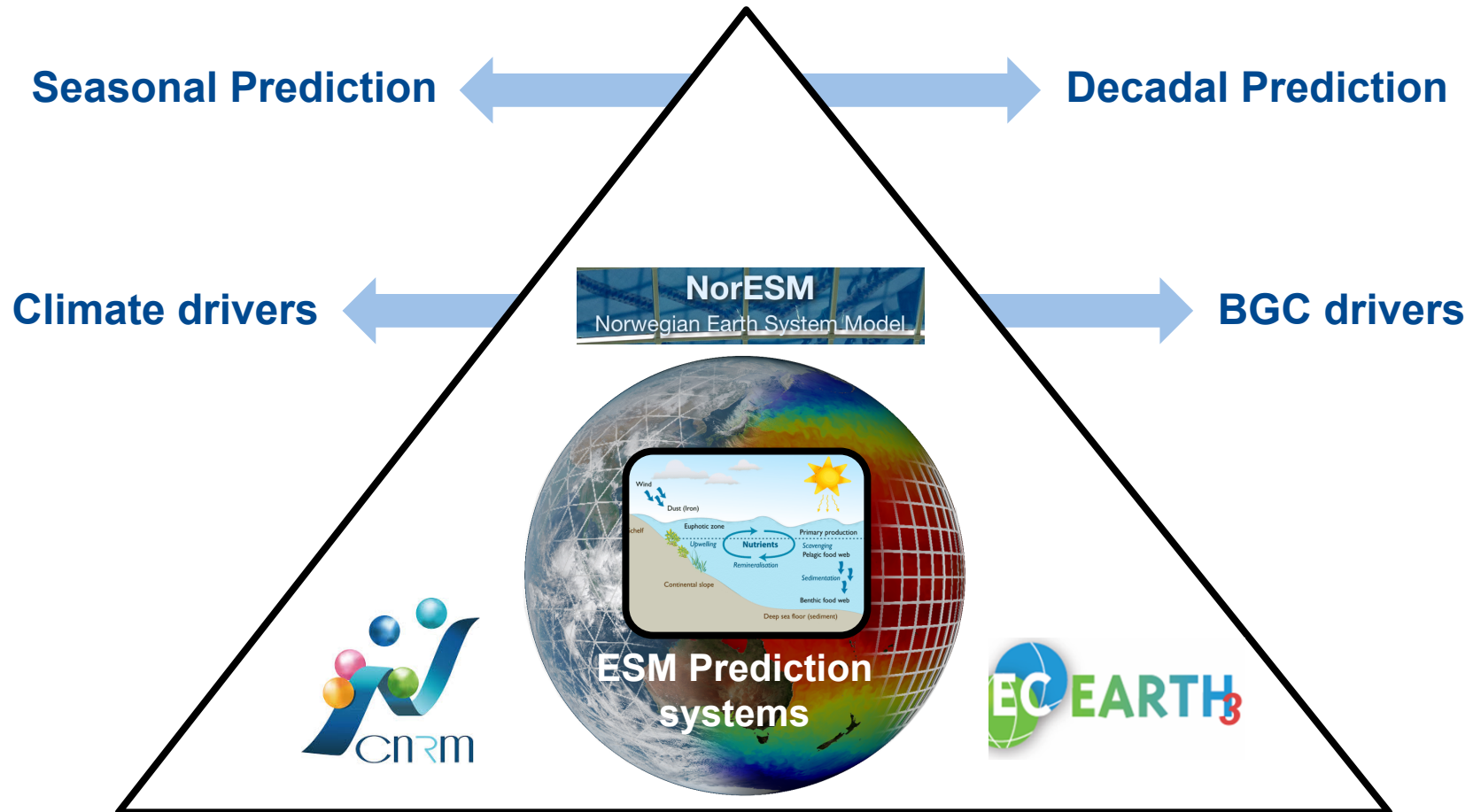
Explore and quantify the **limits of the seasonal to decadal predictability** of relevant climate with **three state-of-the-art ESM** predictions systems



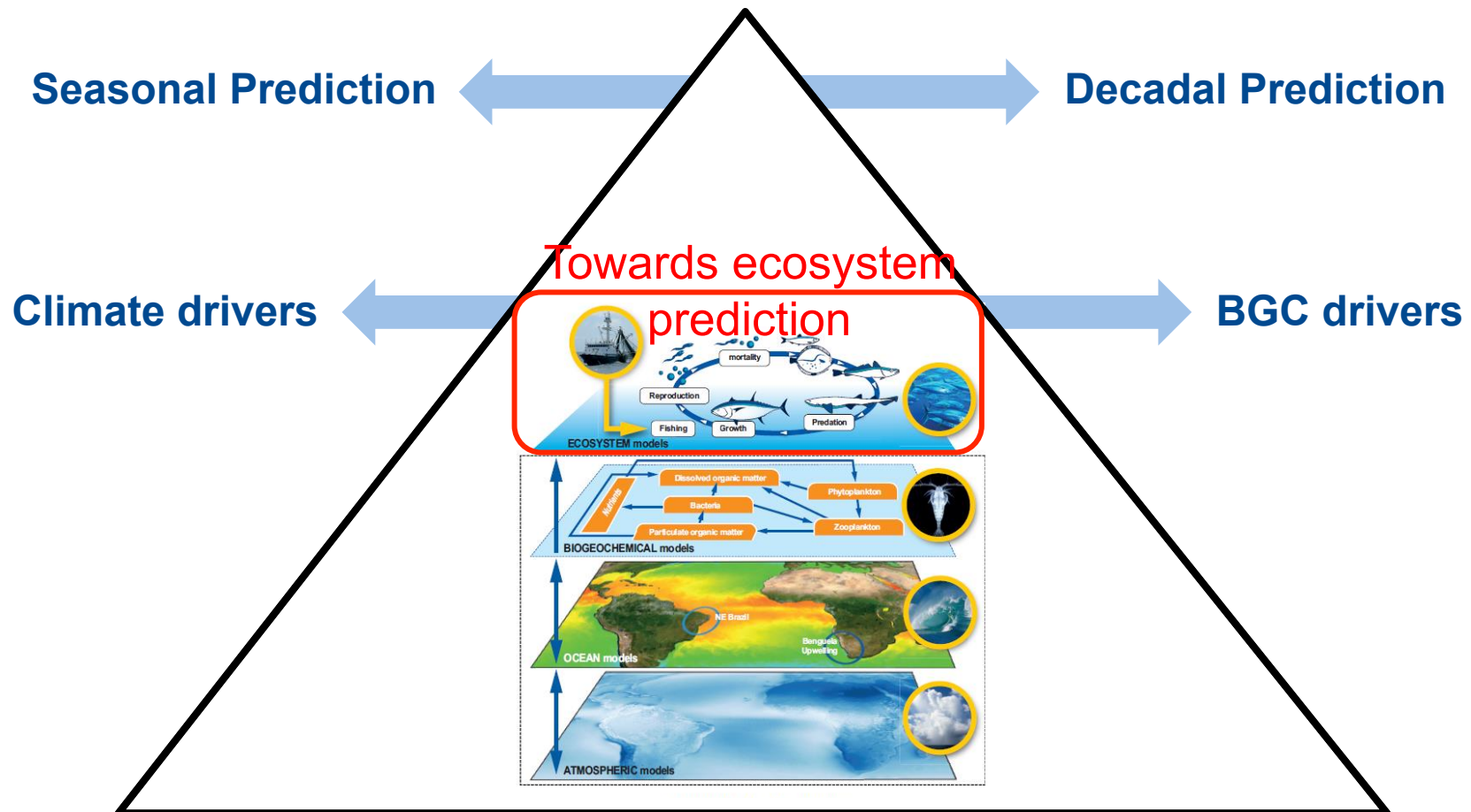
Explore and quantify the **limits of the seasonal to decadal predictability** of relevant climate with **three state-of-the-art ESM** predictions systems



Explore and quantify the **limits of the seasonal to decadal predictability** of relevant climate with **three state-of-the-art ESM** predictions systems



Explore and quantify the **limits of the seasonal to decadal predictability** of relevant climate with **three state-of-the-art ESM predictions systems**



1. Need to **rely on model physics** for reconstructing **past BGC for initialization**, which might limit our predictive capacity
2. The **length of current observations** of ocean BGC might be **too short** to produce **reliable skill verification metrics**
3. Current **model biases** (e.g. in the Tropical Atlantic) **could compromise part of the predictive skill of climate**, BGC and in turn, ecosystem variables

Perfect model analyses emerge as a powerful tool to explore the sensitivity to those and other methodological aspects

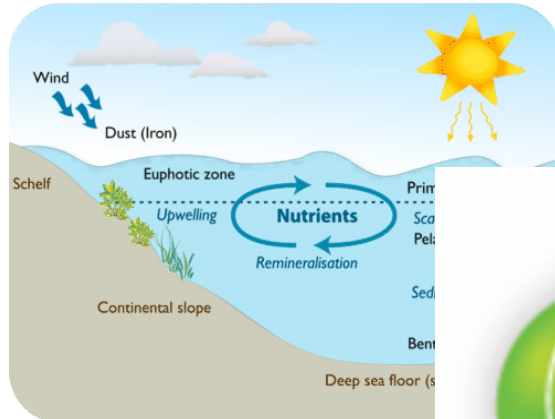
Thanks for your attention!!





## Towards an ESM to study carbon cycle and biosphere

### Marine ecosystems



Hanna Zavadska © CK-12 F

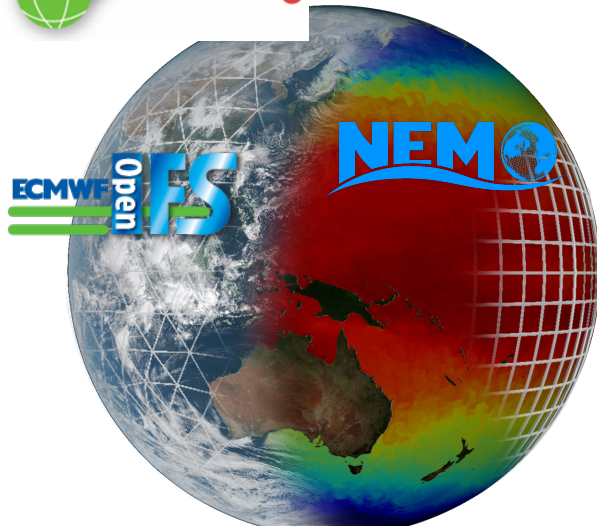
### Carbon cycle



© 2006-20



$$\begin{aligned}\rho_o D_t \vec{v} + 2\Omega \times \rho_o \vec{v} + g\rho \hat{k} + \nabla p &= \vec{F} \\ \rho_o \nabla \cdot \vec{v} &= 0 \\ \partial_t \eta + \nabla \cdot (H + \eta) \vec{v}_h &= P - E \\ D_t \theta &= Q_0 \\ D_t s &= Q_s \\ \rho &= \rho(s, \theta, p)\end{aligned}$$



### Global Climate Model

Model Components

**IFS (Atmospheric Model):**  
T255 (0.75°) ~80km  
L91 (top 0.01hPa) ~mesosphere  
*IFS-HTESSEL (Land Model)*

**NEMO (Ocean Model):**  
Nominal 1° Resolution  
L75 levels (thousands km deep)

**LIM (Sea-ice Model):**  
Multiple (5) ice category

### Global Carbon Cycle Model

**PISCESv2 (Ocean Biogeochemical Model):**  
Lower trophic levels of marine ecosystems

**LPJ-GUESS (Dyn. Glob. Vegetation Model):**  
Process-based, plant functional types

**TM5-CO2 (Atm. Chem. Transport Model):**  
34 layers, single-tracer version (CO2)

# Cornerstones of Numerical Weather Prediction

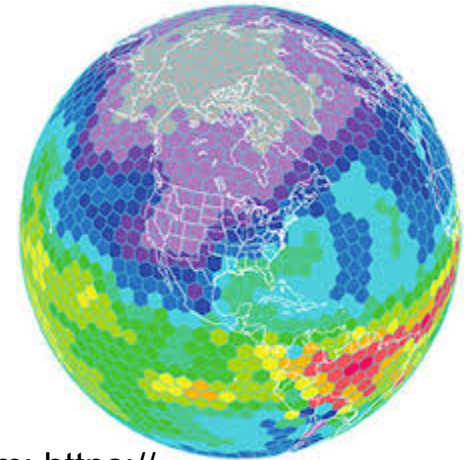
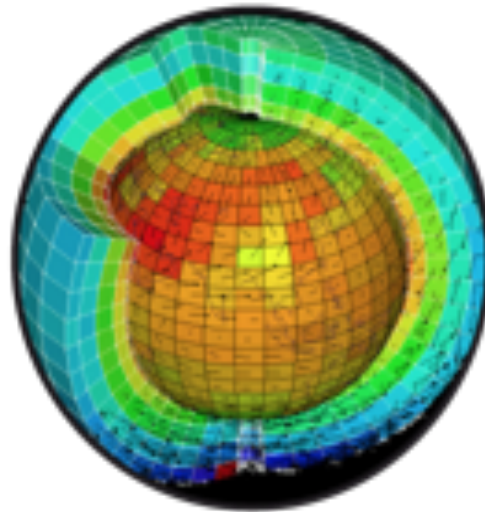
**For a given  
atmospheric state**

**we can solve the  
Governing equations**

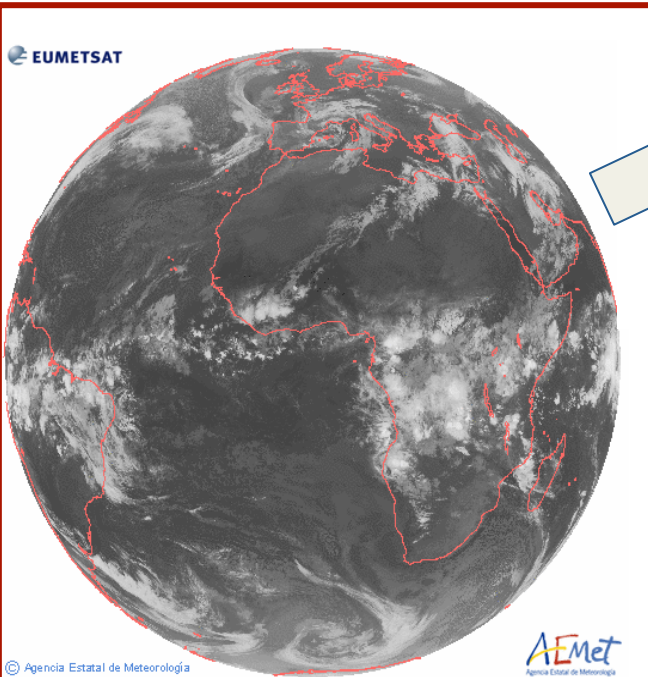
$$\begin{aligned}\rho_0 D_t \vec{v} + 2\Omega \times \rho_0 \vec{v} + g\rho \hat{k} + \nabla p &= \vec{F} \\ \rho_0 \nabla \cdot \vec{v} &= 0 \\ \partial_t \eta + \nabla \cdot (H + \eta) \vec{v}_h &= P - E \\ D_t \theta &= Q_0 \\ D_t s &= Q_s \\ \rho &= \rho(s, \theta, p)\end{aligned}$$

**To make a weather  
prediction**

**within a discretized  
global climate model**



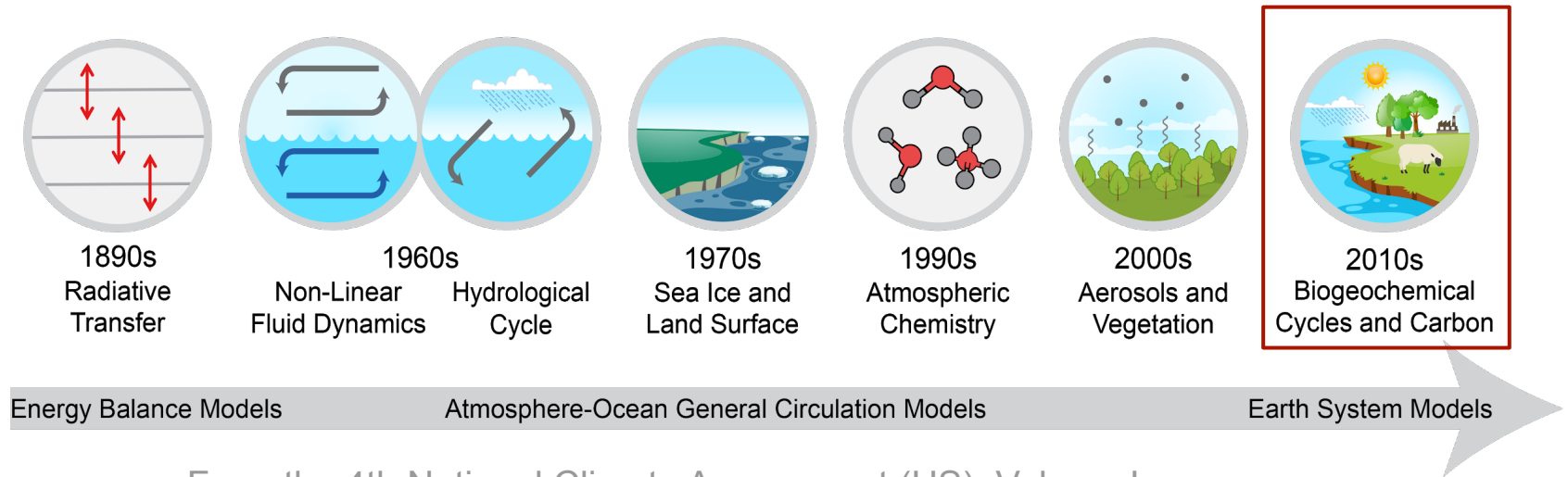
from: [https://  
www.earthsystemcog.org/  
projects/esmf/](https://www.earthsystemcog.org/projects/esmf/)



**Good predictions rely  
on a good initialization  
of the model with  
observational data**

# A climate modeling Timeline

## Inclusion of new components



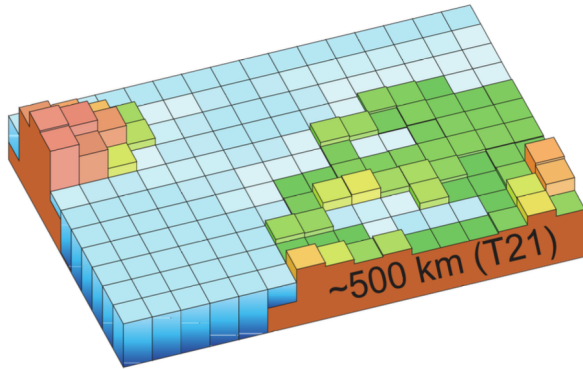
From the 4th National Climate Assessment (US), Volume I

- Allowed the representation of new climate and biogeochemical processes
- Improved the ESMs ability to represent the real world
- Provides a new framework to investigate the interactions between the different components

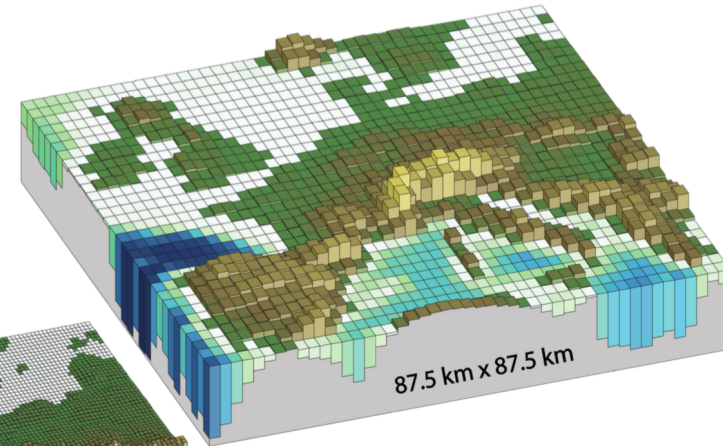
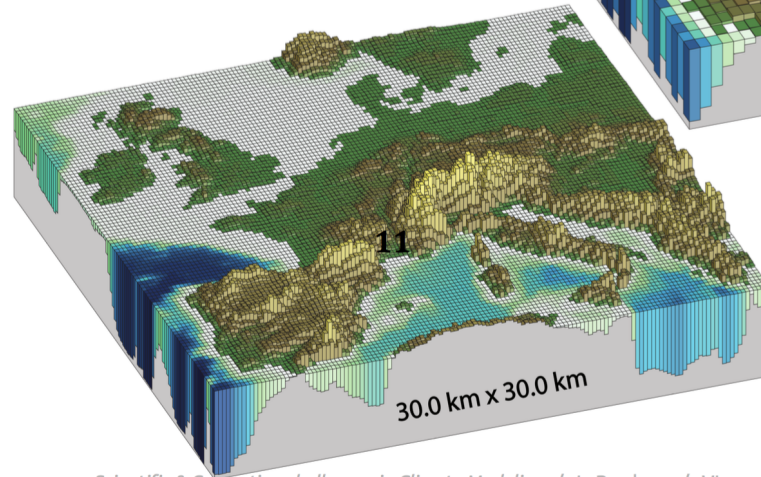
# A climate modeling Timeline

## Increase in spatial resolution: Atmosphere

Typical climate  
model in 90s



Today



Default resolution

“High” resolution

Achieving higher resolutions is essential to better represent orography, and its effect on climate (i.e. in precipitation)



## Contributions to CMIP6

EC-Earth 3.3.1 in standard resolution ( $\sim 1^\circ$ )

### DCPP Component A:

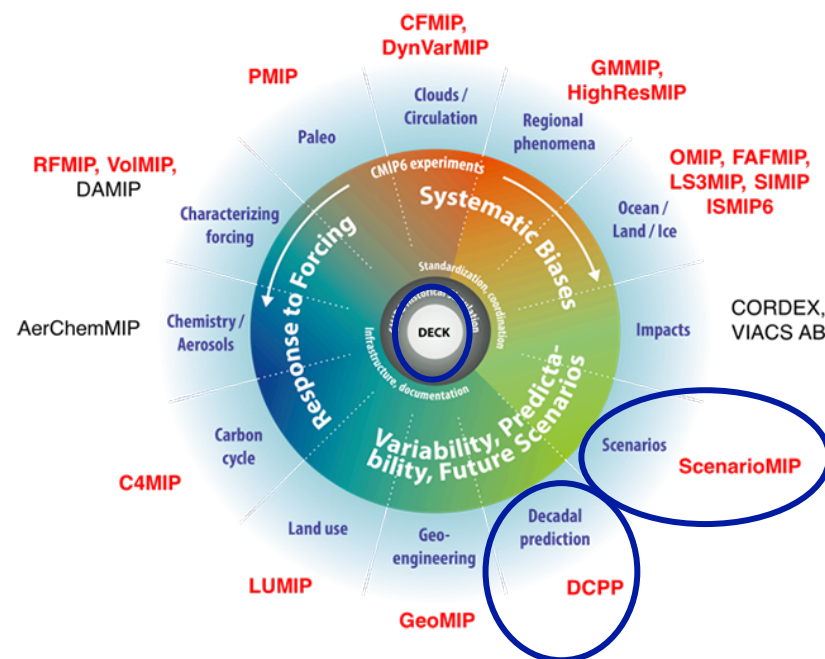
Retrospective Predictions [1960-2017]

### DCPP Component B:

Near-real time Forecasts [2018 onwards]

### DECK+ScenarioMIP:

Historical+SPSS2-4.5 [1850-2100]



## Other H2020 activities

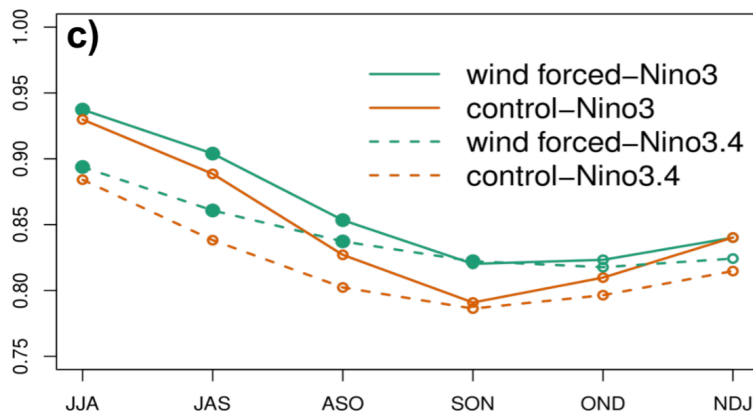
With EC-Earth 3.3.1 in high resolution ( $\sim 0.25^\circ$ )



### DCPP Component A-like:

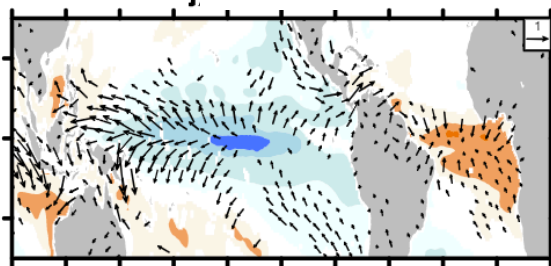
Retrospective Predictions [1960-2017]

## ACC for NINO34

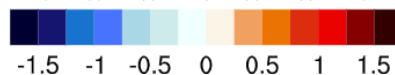
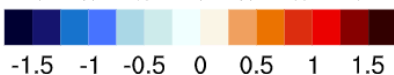
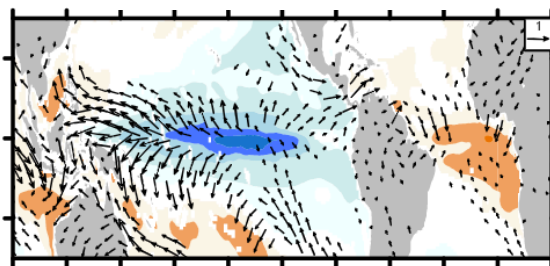


## Regression JJA ATL3 vs SON SST

CTRL



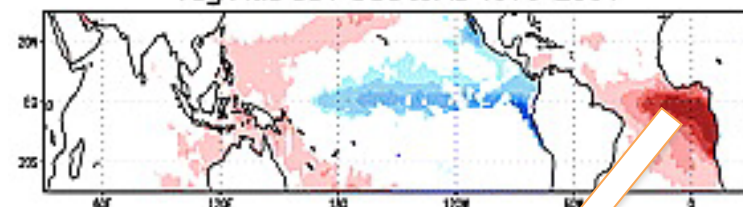
Wind corrected



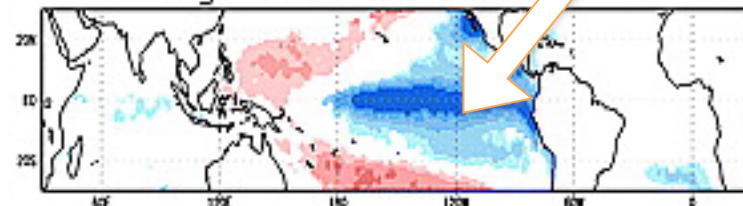
Exarchou et al. (in preparation)

## Observed teleconnection of Atlantic Niño with winter NIÑO

reg Atl3 SST OBS JJAS 1979-2001



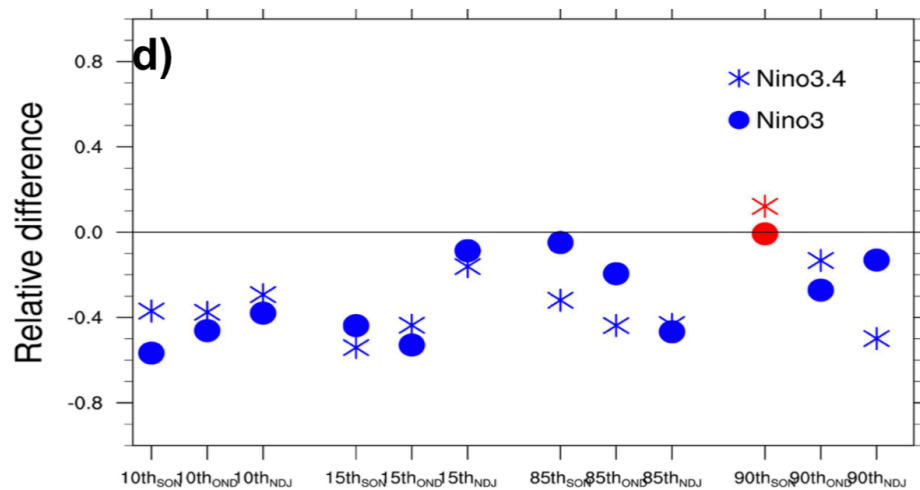
reg Atl3 SST OBS DJFM 1979-2001



Rodriguez-Fonseca et al (2009)

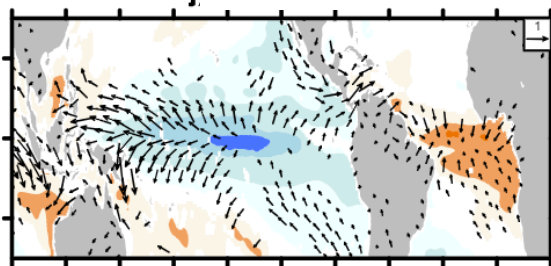


## Relative difference Brier Score (Wind-CTRL)

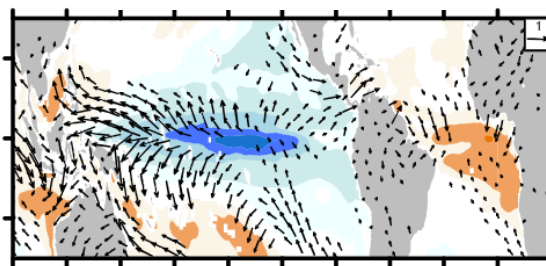


## Regression JJA ATL3 vs SON SST

CTRL

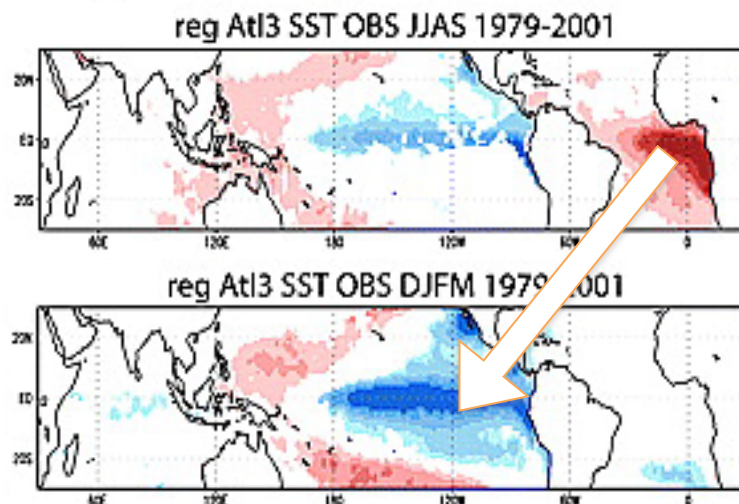


Wind corrected



Exarchou et al. (in preparation)

## Observed teleconnection of Atlantic Niño with winter NIÑO



Rodriguez-Fonseca et al (2009)

